International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R SM.2028-0
(09/2012)

Protection distance calculation between inductive systems and radiocommunication services using frequencies below 30 MHz

SM Series
Spectrum management

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2012

RECOMMENDATION ITU-R SM.2028-0*

Protection distance calculation between inductive systems and radiocommunication services using frequencies below 30 MHz

(2012)

Scope

This Recommendation addresses the compatibility between inductive systems operating at frequencies below 30 MHz and the existing radiocommunication services and provides a summary of a straightforward procedure to calculate the protection distance to protect radiocommunication services with regard to interference by inductive systems.

Keywords

Protection distance calculation, compatibility, inductive systems

The ITU Radiocommunication Assembly,

considering

a) that there is an increasing demand for the usage of inductive systems including induction cooking appliances which are operating at the frequency bands below 30 MHz;

b) that there is interference potential of inductive systems to the existing radiocommunication services;

c) that the protection distance of radiocommunication services should be established to assess the impact of interference from inductive systems,

noting

a) that Recommendation ITU-R SM.1056 considers the latest edition of CISPR Publication 11**, as a guide for the application of limits and methods of measurements for ISM devices in order to protect radiocommunications;

b) that Report ITU-R SM.2180 – Impact of industrial, scientific and medical (ISM) equipment on radiocommunication services, introduces applications of ISM equipment, characteristics of radiation and analysis of potential interference to emphasize on the protection of radiocommunication services from ISM equipment,

recommends

1 that administrations take all necessary precautions to ensure that inductive systems operating on frequency bands below 30 MHz should not cause interference to radiocommunication services;

2 that in establishing protection method of radiocommunication services, administrations should take into account a calculation procedure of protection distance between inductive system and radiocommunication services, as given in Annex 1.

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* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2019 and 2023 in accordance with Resolution ITU-R 1.

** The emission requirements for domestic induction cookers have been transferred from CISPR Publication 11 to Publication 14-1 with no technical changes.

Annex 1

A method of protection distance calculation

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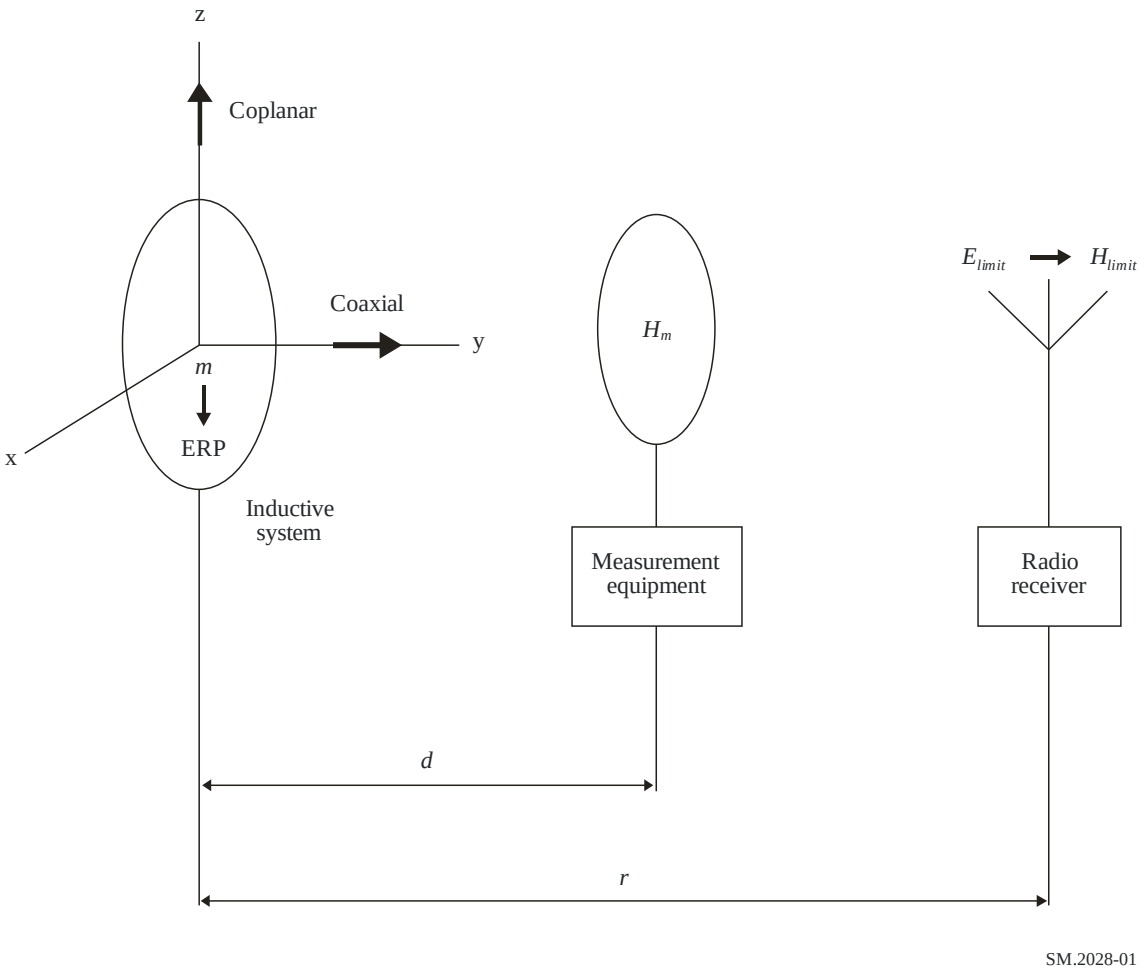
1 Interference scenario model

In general, the effective radiated power level of inductive systems can be calculated from magnetic dipole moment. The magnetic dipole moment which is the product of the total current in the inductive loop multiplied by the surface area can be determined from the measured magnetic field strength at a certain distance by using Maxwell equations. The radiated power level can be applied to existing service as an interferer. The electric field strength of interference from inductive system should be less than the interference limit of electric field strength of victim service. Thereby it is required that the protection distance be defined to protect the existing service. The practical interference scenario is shown in Fig. 1.

FIGURE 1

Interference scenario model



2 Calculation procedure of radiated power of an inductive system

The magnetic field strength H_m (A/m)[1] of an inductive system is measured by measurement equipment at a certain distance d (metres) and it has two radiation directions as coaxial direction and coplanar direction. The coaxial direction is on the axis of the inductive loop and the coplanar direction is in the plane of the loop. In addition, the radiation direction is determined by the cross-over point of the coaxial curve and the coplanar curve. The cross-over point is positioned at $2.354 \times \lambda_r$ (metres) from the magnetic dipole. Here, λ_r means the radian wavelength which is equal to $\lambda/2\pi$ and λ is the wavelength. When the magnetic field strength is measured at a shorter distance than the cross-over point, the magnetic dipole moment m_1 (Am^2) in the coaxial direction can be calculated:

$$m_1 = \left|H_m\right| \cdot \frac{2\pi\lambda_r d^3}{\sqrt{\lambda_r^2 + d^2}} \quad (1)$$

When the magnetic field strength is measured at a longer distance than the cross-over point, the magnetic dipole moment m_2 (Am^2) in the coplanar direction can be computed by:

[1] The unit of the limits and measurement of the magnetic field strength quoted in dB(μA/m) is equivalent to 20 log H (A/m) + 120.

$$m_2 = \left|H_m\right| \cdot 4\pi \frac{\lambda_r{}^2 d^3}{\sqrt{\lambda_r{}^4 - \lambda_r{}^2 d^2 + d^4}} \quad (2)$$

The effective radiated power (ERP) (kW) level of an inductive system can be derived:

$$ERP = \frac{1}{1000} \cdot \frac{20}{\lambda_r{}^4} \cdot (m)^2 \quad (3)$$

Here, m is the maximum of m_1 and m_2.

3 Calculation of electric field strength limit of a victim service

There are two ways to determine the electric field strength limit of a victim service E_{limit} (dB(μV/m)). One is to consider the noise level and another is to consider the signal-to-noise ratio (*SNR*). The method considering noise level is as follows.

E_{noise} (dB(μV/m)) of a victim service is corrected for the bandwidth of the victim receiver:

$$E_{noise} = E_{noise,b} + 10 \log \left(b_{victim} / b_{noise}\right) \quad (4)$$

Here, b_{noise} is the measuring bandwidth of noise, b_{victim} is the bandwidth of victim and $E_{noise,b}$ is electric field strength of noise from Recommendation ITU-R P.372.

In case of broadband interference, the bandwidth ratio (*BWR*) (dB) should be included to calculate the electric field strength limit:

$$E_{limit} = E_{noise} + BWR \quad (5)$$

The bandwidth ratio is defined:

$$BWR = 10 \log \left(b_{measuring} / b_{victim}\right) \quad (6)$$

Here, $b_{measuring}$ is the measuring bandwidth of interferer.

When the bandwidth of the interfering signal is not wider than the victim receiver bandwidth, *BWR* = 0 dB should be assumed.

The method considering *SNR* is as follows.

In the case where the minimum field strength E_{min} (dB(μV/m)) and the *SNR* (dB) are known, the electric field strength limit is calculated:

$$E_{limit} = E_{min} - SNR + BWR \quad (7)$$

From the electric field strength limit, the magnetic field strength limit H_{limit} (A/m) can be obtained:

$$H_{limit} = 10^{\frac{E_{limit} - 120 - 51.5}{20}} \quad (8)$$

4 Protection distance calculation for propagation model

The complete coverage range can be divided into four sub-ranges. Usually, the propagation models are described as ground wave model and free space model.

At distances less than a roll-off of 40 dB/decade, $r > d_{tr}$ and $r > \lambda_r \times 2.354$, the protection distance (metres) can be calculated:

$$r = 1000 \cdot 10^{\frac{E_{int} - E_{limit}}{40}} \quad (9)$$

where d_{tr} (metres) is the transition distance at the point of intersection between a roll-off of 40 dB/decade and a roll-off of 20 dB/decade.

E_{int} (dB(μV/m)) is interference level at a distance of 1 km and can be calculated:

$$E_{int} = E_{asymptote,40} + ERP_{dB} \quad (10)$$

where $E_{asymptote,40}$ (dB(μV/m)) is determined by 40 dB/decade asymptote at 1 km distance for a radiated power of 1 kW as in Recommendation ITU-R P.368 and ERP_{dB} (dB(kW)) is obtained by 10log(*ERP*).

At distances of a roll-off of 20 dB/decade, $r > \lambda_r \times 2.354$, the protection distance is calculated by using the following formula:

$$r = 10^{\frac{120 + 49.5 + ERP_{dB} - E_{limit}}{20}} \quad (11)$$

When the ranges are close to the near field, $r > \lambda_r$, the protection distance is determined:

$$r = \sqrt{\frac{m}{H_{limit} \lambda_r 2\pi}} \quad (12)$$

When the ranges are within the near field, $r > \lambda_r$, the protection distance can be calculated by the following equation:

$$r = \sqrt[3]{\frac{m}{2\pi H_{limit}}} \quad (13)$$

5 Flow chart for protection distance calculation

A simple procedure of protection distance calculation is explained in terms of a flow chart:

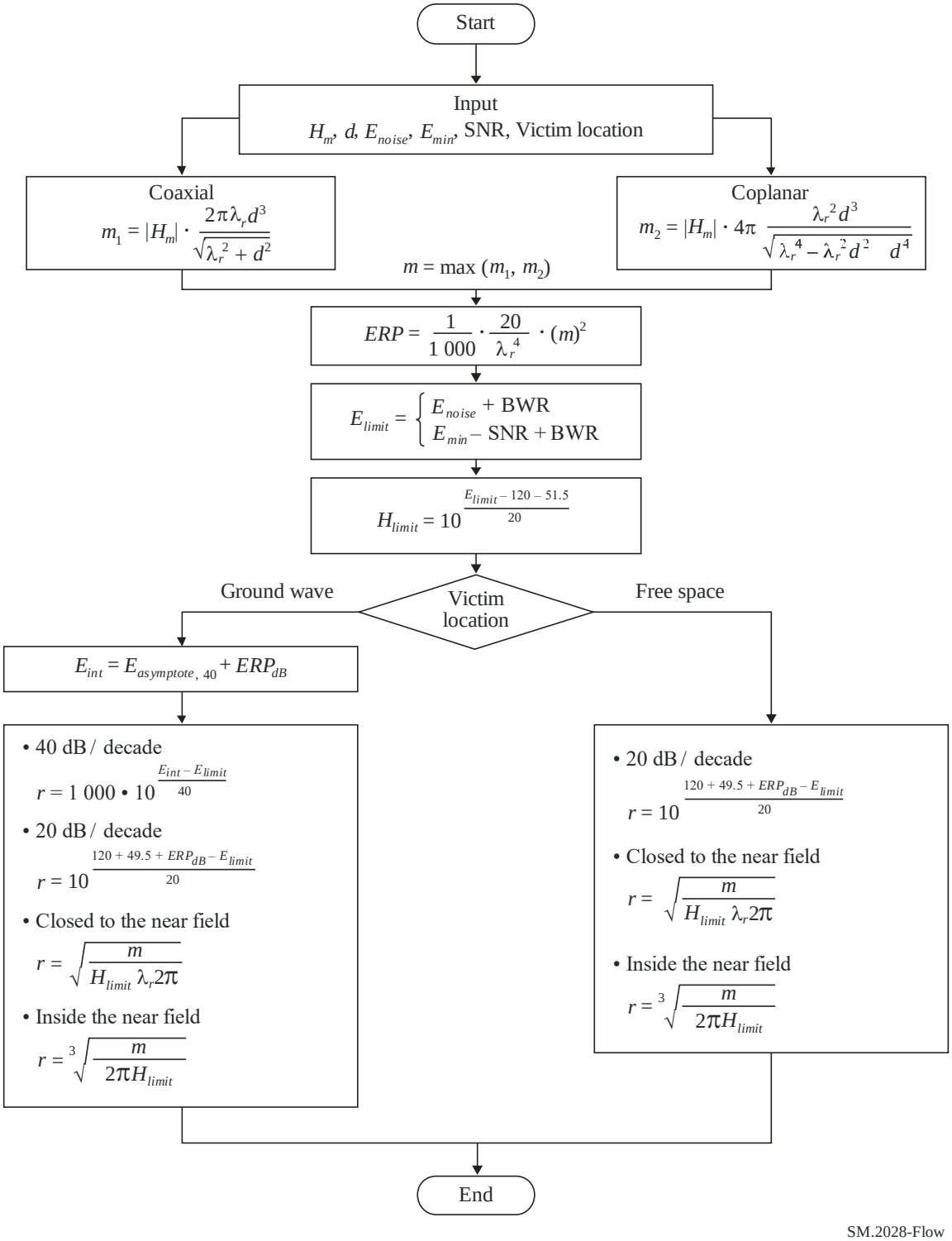


Table 1 describes the $E_{asymptote,40}$ presented in Recommendation ITU-R P.368.

TABLE 1

Data presented in Recommendation ITU-R P.368

Table of field strength of the 40 dB/dec. roll-off asymptote at the distance of 1 km by an effective radiated power of 1 kW (symbolic value for long path calculation), derived from Recommendation ITU-R P.368 (dB(μV/m)): $E_{asymptote,40}$												
Ground type		1	2	3	4	5	6	7	8	9	10	11
σ		1	5	$3e^{-3}$	$30e^{-3}$	$10e^{-3}$	$3e^{-3}$	$1e^{-3}$	$3e^{-4}$	$1e^{-4}$	$30e^{-6}$	$10e^{-6}$
ε		80	70	80	40	30	22	15	7	3	3	3
10	kHz	166	166	165	167	165	165	165	164	163	159	151
15		164	165	164	165	163	164	164	163	160	154	144
20		163	164	163	164	163	163	163	162	157	149	139
30		162	163	162	163	162	163	161	158	152	142	132
40		162	162	161	162	161	162	160	155	148	137	128
50		161	161	159	162	161	161	158	152	144	133	124
75		160	160	157	161	159	158	154	146	137	126	119
100		159	159	155	160	158	156	150	142	132	121	116
150		158	158	151	158	156	153	144	134	124	115	112
200		158	158	147	157	154	148	140	129	119	111	109
300		157	157	141	155	150	142	132	122	112	107	106
400		156	156	136	153	147	135	127	117	107	104	103
500		156	155	132	150	143	134	123	113	103	102	102
750		154	154	126	146	137	127	117	107	98	98	98
1.0	MHz	152	153	122	142	132	120	112	103	96	96	96
1.5		151	153	118	135	124	114	107	98	92	92	92
2.0		150	152	115	129	119	109	103	95	89	89	89
3.0		147	151	111	123	112	103	98	93	86	86	86
4.0		144	149	108	117	107	99	95	90	83	84	83
5.0		142	148	107	113	103	97	93	87	81	82	82
7.5		136	146	103	105	97	93	89	84	78	78	78
10		132	143	101	100	94	90	87	81	76	76	76
15		126	138	97	95	89	87	83	77	72	72	72
20		120	134	95	91	87	84	81	75	70	70	70
30		113	127	91	87	83	80	77	72	66	66	66

Here, σ and ε are conductivity and permittivity, respectively.

6 Example

This section shows an example of the protection distance between induction cooking appliances (interferer) and AM broadcasting receivers (victim) at 30 MHz using the presented calculation method.

CISPR Publication 14-1[2] contains the limit of radiation generated by induction cooking appliances and the radiated H-field limits of CISPR Publication 14-1 in Table 2 and Fig. 2 are used for the interference level of induction cooking appliances. The external radio noise is used as the protection criteria of AM receiver in this example. Note that the protection criteria may be changed depending on a variety of victim receiver performance criteria.

TABLE 2

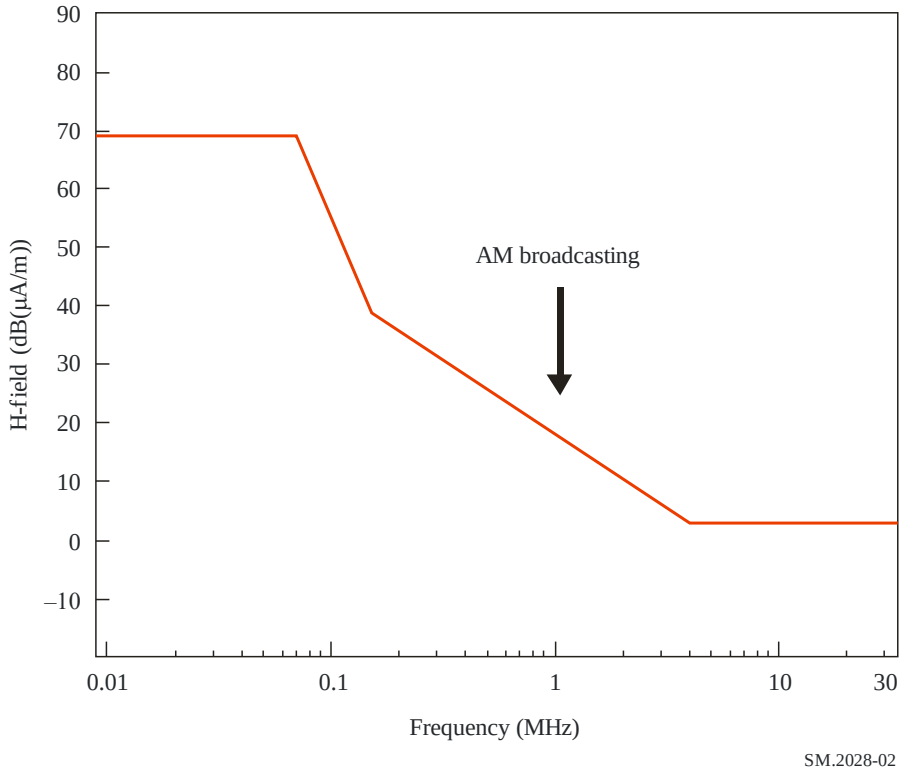
Limits of the magnetic field strength

Frequency range (MHz)	**Limits at 3 m distance quasi-peak (dB(μA/m))**
0.009 ~ 0.07	69
0.07 ~ 0.1485	69 decreasing linearly with logarithm of frequency to 39
0.1485 ~ 4	39 decreasing linearly with logarithm of frequency to 3
4 ~ 30	3
The limits of this apply to induction cooking appliances intended for commercial use and those for domestic use with a diagonal diameter of more than 1.6 m. The measurements are performed at 3 m distance with a 0.6 m loop antenna as described in § 4.2.1 of CISPR 16-1-4. The antenna shall be vertically installed, with the lower edge of the loop at 1 m height above the floor.	

[2] The emission requirements for domestic induction cookers have been transferred from CISPR Publication 11 to Publication 14-1 with no technical changes. During the transition period, from November 2011 to June 2015, both standards were in effect on these appliances.

FIGURE 2

Limit of the magnetic field strength



The interference level of 18 dB(µA/m) for induction cooking appliance is determined according to frequency of AM broadcasting (1 MHz) in Fig. 2. In this case, the limit of magnetic field strength of 18 dB(µA/m) can be assumed to be measured at the distance of 3 m.

In CISPR Publication 14-1 for induction cooking appliances, the measuring bandwidth is 9 kHz for frequency range from 150 kHz to 30 MHz and the measuring distance is 3 m. Therefore, it is defined that $b_{measuring}$ is 9 kHz and d is 3 m. $E_{asymptote,40}$ of 120 dB(µV/m) is obtained from 1 MHz frequency and ground type 6 in Table 1.

The noise level approach is used to get E_{limit}. The $E_{noise,b}$ of 9 dB(µV/m) and the b_{noise} of 2.7 kHz are given in Recommendation ITU-R P.372. The b_{victim} of 4.4 kHz is used for AM broadcasting. The E_{noise} of 11.12 dB(µV/m) and BWR of 3.11 dB are calculated by using equations (4) and (6), respectively. Then E_{limit}, maximum allowable interference level, is obtained as 14.23 dB(µV/m) by using equation (5).

When the electric field strength at 1 km distance from ERP of 1 kW is given as 109.5 dB(µV/m) for the roll-off of 20 dB/decade in Recommendation ITU-R P.368 and $E_{asymptote,40}$ is 120 dB(µV/m), the d_{tr} of 3 349.65 m is computed by $1000 \times 10^{-(109.5 - 120)/20}$. Finally, the protection distance (r) is obtained by computing the effective radiated power (ERP_{dB}) and the magnetic dipole moment (m) as in § 4.

TABLE 3

Calculation of protection distance

Input data	
Frequency	1 000 kHz
Magnetic field strength (H_m)	18 dB(μA/m)
Measuring distance (d)	3 m
$E_{asymptote,40}$ from Rec. ITU-R P.368 (see equation (10))	120 dB(μV/m)
Electric field noise level from Rec. ITU-R P.372 ($E_{noise,\ b}$)	9 dB(μV/m) in 2.7 kHz
Bandwidth of the victim receiver (b_{victim})	4.4 kHz
Measuring bandwidth ($b_{measuring}$)	9 kHz
Result	
Maximum allowable interference level (E_{limit})	14.23 dB(μV/m)
Transition distance (d_{tr})	3 349.65 m
Bandwidth ratio (BWR)	3.11 dB
Maximum direction	Coaxial
Magnetic dipole moment (m)	0.001344 Am^2
Effective radiated power (ERP_{dB})	–141.58 dB(kW)
Protection distance (r)	25 m